

but that situation will soon change. In response to a request by the U.S. Department of Education, the National Research Council has proposed a comprehensive study that will not only examine the achievement of students whose education is financed or supplemented by vouchers, but will also examine the policy consequences, such as the impact vouchers have on the public school system (White 1999).

Student Achievement

Trends in National Achievement

The National Assessment of Educational Progress (NAEP) has monitored educational performance through its trends series (which is distinguished from other NAEP series) since 1969. To facilitate comparisons, the same instruments have been used in every trend assessment since that time. NAEP trend results are reported in terms of average scale scores and in terms of five proficiency levels or anchor points. The five anchor points correspond to five levels of performance, ranging from the basic skills and knowledge to be mastered in the earliest years (Skill Level 150) to the fluency needed to solve challenging problems (Level 350). Most of the NAEP results included in this chapter are based on the latter. (See sidebar, “Proficiency Levels Used in NAEP Science and Mathematics Trends Assessments.”)

NAEP trends results from the last 20 years indicate that, for the most part, students are performing at higher levels in

mathematics and science than did their counterparts in the late 1970s. However, the data also suggest that performance falls below expectations based on new educational standards (NCES 1997a).

Elementary and Middle School Science and Mathematics

At the high school level, the primary function of the mathematics and science curricula is to begin the preparation of future scientists, mathematicians, and engineers, which was the goal of educational reforms in the 1960s. In turn, the primary function of elementary and middle school science and mathematics is to lay the groundwork for high school curricula in these areas. In other words, elementary and middle schools are expected to provide the building blocks that students will need in order to progress through the science and engineering pipeline in later years. These early years are quite critical, particularly for mathematics. According to several respected educators, it is in elementary school that young children begin constructing a knowledge base to build upon as they progress to higher levels of knowledge, skill, and understanding (Campbell and Johnson 1995). This section of the chapter examines the adequacy of elementary, middle, and high school preparation, as reflected by NAEP achievement results.

The science and mathematics achievement of both 9- and 13-year-old students has improved significantly since 1977/78. In science, about two-thirds of 9-year-olds reached Level

Proficiency Levels Used in NAEP Science and Mathematics Trends Assessments

Level	Science	Mathematics
350	Integrates Specialized Scientific Information Can infer relationships and draw conclusions using detailed scientific knowledge.	Multistep Problem Solving and Algebra Can solve multistep problems and use algebra.
300	Analyzes Scientific Procedures and Data Has some detailed scientific knowledge and can evaluate the appropriateness of scientific procedures.	Moderately Complex Procedures and Reasoning Can compute with decimals, fractions, and percents; recognize geometric figures; solve simple equations; and use logical reasoning to solve problems.
250	Applies General Scientific Information Understands and applies general information from the life and physical sciences.	Numerical Operations and Beginning Problem Solving Can add, subtract, multiply, and divide using whole numbers and can solve one-step problems.
200	Understands Simple Scientific Principles Understands some simple principles and has some knowledge, particularly about physical sciences.	Beginning Skills and Understanding Can add and subtract two-digit numbers and recognize relationships among coins.
150	Knows Everyday Science Facts Knows some general science facts.	Simple Arithmetic Facts Knows some addition and subtraction facts.

SOURCE: National Center for Education Statistics (NCES). 1997. NAEP 1996 Trends in Academic Progress. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

200 in 1977, showing that they could understand some simple scientific principles. Between 1977 and 1996, the proportion reaching this level increased so that on the most recent assessment, roughly three-quarters of students demonstrated that capacity. Approximately 26 percent of 9-year-olds met or exceeded Level 250 in 1977, showing that they could apply general information from the life and physical sciences. That number increased to 32 percent in 1996.

The proportion of 13-year-old students reaching achievement Levels 200 and 250 in science also increased between the first and the most recent trends assessments. Eighty-six percent or more of 13-year-olds showed understanding of simple scientific principles (Level 200) in 1977, while 92 percent performed at the level in 1996. Level 250 performance demonstrates some capability to apply life- and physical-science concepts. Approximately 49 percent of 13-year-olds reached or exceeded that level in 1977 and about 58 percent did so in 1996. (See figure 5-4.)

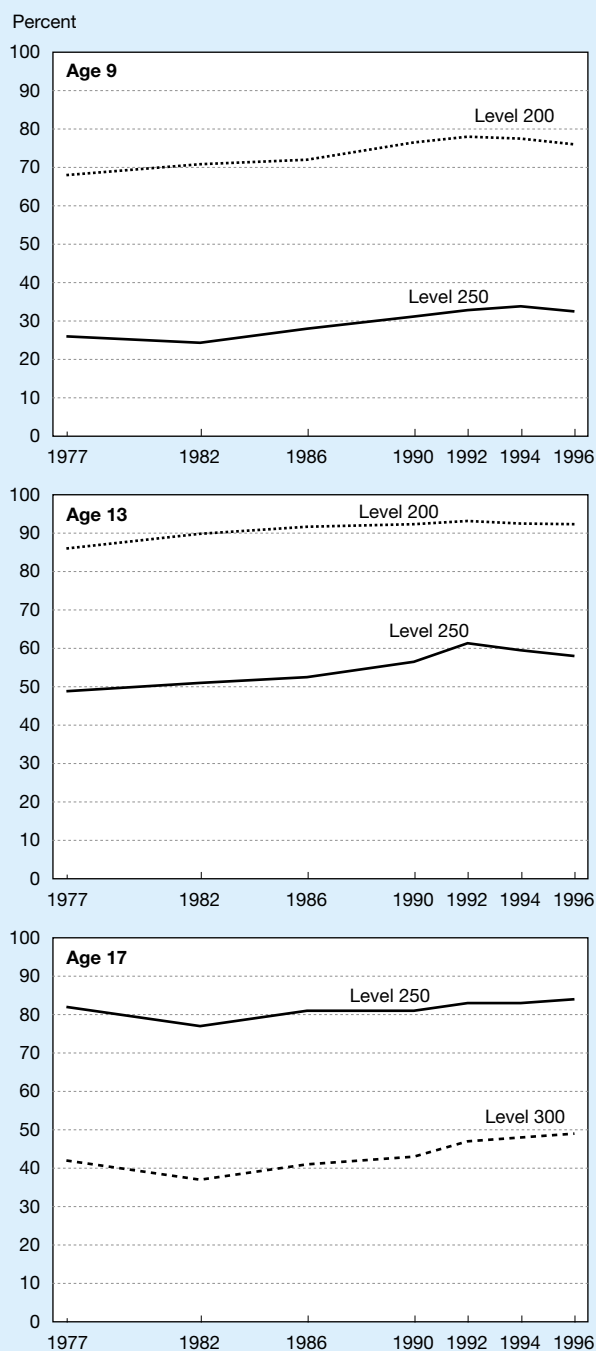
The mathematics achievement of elementary and middle school aged children also improved between 1978 and 1996. (See figure 5-5.) At Level 200, students are able to add and subtract two-digit numbers and recognize some coins. The percentage of 9-year-olds achieving that level was 70 percent in 1978 and increased to 82 percent in 1990, after which it remained stable through 1996. At Level 250, students can perform the basic four mathematical operations (addition, subtraction, multiplication, and division) and can solve one-step problems. In 1978, approximately 20 percent of 9-year-olds performed at this level. The numbers grew to 30 percent in 1996.

The number of 13-year-olds demonstrating command of the basic operations of mathematics (Level 250) grew from 65 percent in 1978 to 79 percent in 1996. At Level 300, students are able to compute with decimals and fractions, recognize geometric figures, solve simple equations, and use moderately complex reasoning. Approximately 18 percent of students demonstrated these skills in 1978 compared to 21 percent in 1996, which was not significantly higher.

High School Achievement

There were also some gains among 17-year-old students in science and mathematics from 1977 to 1996. (See figures 5-4 and 5-5.) In 1977, 82 percent of 17-year-olds met or exceeded Level 250 on the science assessment, the stage at which students can apply principles of life and physical sciences. There was an upward trend in the performance of students achieving at this level between 1977 and 1996, but the 84 percent in 1996 was not significantly different from the 1977 findings. Forty-two percent of 17-year-olds achieved Level 300 in 1978, where students are presumed to have some detailed scientific knowledge and the capacity to evaluate the appropriateness of scientific procedures. The percentage of high school students demonstrating benchmark performance ranged from 37 percent in 1982 to 48 percent in 1996. The overall pattern of science performance increase between 1977 and 1996 performance was significant. (See figure 5-4.)

Figure 5-4.
Trends in the percentage of students at or above benchmark levels of NAEP science performance, by age: 1977–96

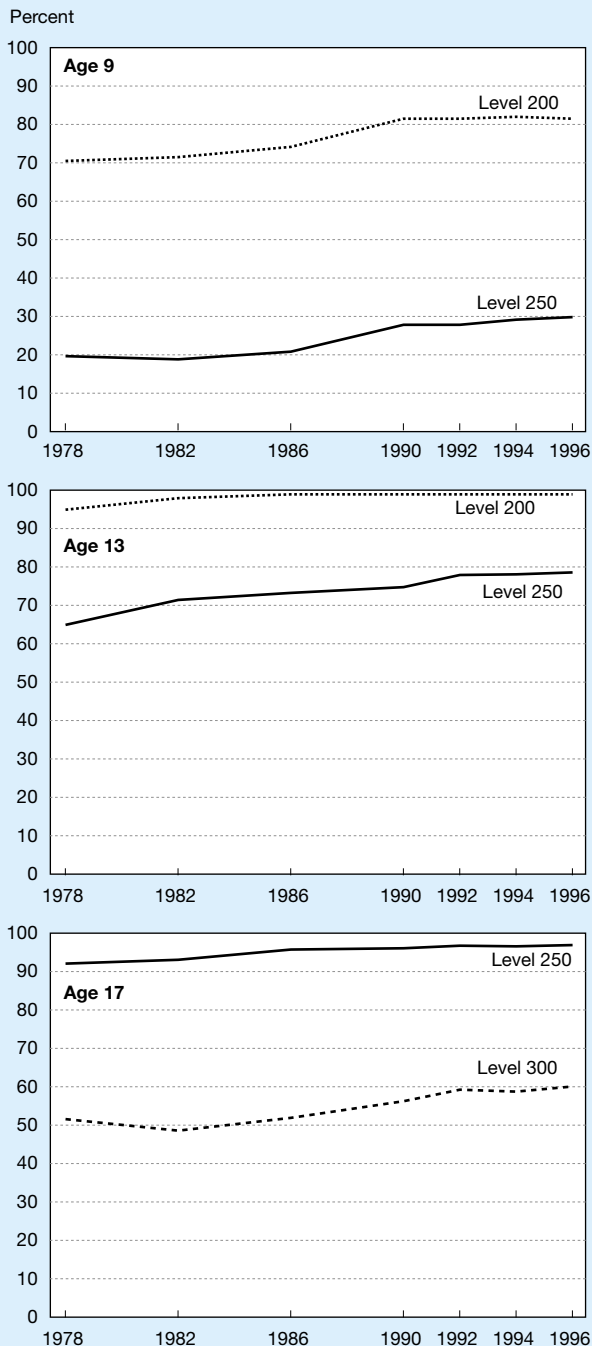


NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress*. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-6, 5-7, and 5-8.

Figure 5-5.
Trends in the percentage of students at or above
benchmark levels of NAEP mathematics
performance, by age: 1978–96



NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997.
NAEP 1996 Trends in Academic Progress. NCES 97-985.
Washington, DC: U.S. Department of Education, Office of Educational
Research and Improvement.

See appendix tables 5-9, 5-10, and 5-11.

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In 1978, approximately 92 percent of 17-year-old students functioned at or above Level 250 in mathematics, showing that they could solve one-step problems. (See figure 5-5.) The 5 percentage-point difference between the 1977 numbers and the overall upward trend were statistically significant. Approximately 52 percent of 17-year-old students functioned at a higher complex reasoning stage (Level 300) in 1978 and 60 percent in 1996, a statistically-significant increase in the change of percentage points.

Achievement Trends by Demographic Group

The proportion of females and underrepresented minorities still remains low at every point along the science, mathematics, and engineering pipeline. For these reasons, it is of interest to monitor mathematics and science performance of these demographic groups from elementary school through high school.

Gender Differences in Performance. The chapter on higher education reports that the number of females who receive bachelor's degrees in natural science fields has increased in the past ten years but that the number of women in mathematics and computer science fields has not increased since 1985. Therefore, the performance of students on mathematics tests in elementary and secondary school is of concern as an indicator of the preparation of students for college performance in mathematics and science.

NAEP performance levels for male and female students are presented for science in text table 5-3 and for mathematics in text table 5-4. A higher proportion of both male and female 9-year-olds reached benchmark science performance in 1996 than in 1978. Between 1977 and 1996, the performance levels of boys and girls were not distinguishable. For 13-year-olds, significant increases also occurred for both boys and girls between 1977 and 1996; however, at this age, boys have slightly higher proportions with performance in science above 250 (62 percent of boys and 54 percent of girls). At age 17, the performance of both males and females increased between 1977 and 1996 but males were more likely than females to get scores of 300 or more in 1996. (See text table 5-3.) By 1996, the difference in the proportion of males and females scoring at 300 or more was about 9 percentage points. Thus, in science performance, the tendency of males to perform at higher levels than females at older ages continues to exist.

In mathematics, differences between males and females are much more difficult to detect than for science. At ages 9 and 13, the percentage of males and females reaching the benchmark on the mathematics assessment (Level 200 at age 9 and 250 at age 13) increased from 1978 to 1996. There had been no significant difference for boys and girls age 13 since 1978. For 17-year-olds, the mathematics performance of both genders increased significantly from 1978 to 1996 but the differences in the performance of male and female students has not formed a consistent trend. The figures in text table 5-4 suggest a closing of the gap between males and females (males were a few percentage points higher in 1978, 1982,

Text table 5-3.

Trends in the percentage of students at or above benchmark levels of science performance, by age and sex: 1977–96, selected years

Years	Male	Female
Age 9		
Level 200		
1977	70	67
1982	70	72
1986	74	70
1990	76	76
1992	80	76
1994	78	77
1996	77	76
Age 13		
Level 250		
1977	52	45
1982	56	46
1986	57	48
1990	60	53
1992	63	60
1994	62	57
1996	62	54
Age 17		
Level 300		
1977	49	35
1982	45	30
1986	49	34
1990	48	39
1992	51	42
1994	53	42
1996	53	44

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress*. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-6, 5-7, and 5-8.

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and 1986), but no evidence of a further closing of the gap was observed between 1990 and 1996. Among 17-year-olds, males increased their achievement in the 1990s whereas females did not have significant increases in performance between 1990 and 1996. The apparent difference between male and female 17-year-olds in 1996 was not statistically significant.

Gender differences in student performance on mathematics and science assessments were also examined globally in the reports of Third International Mathematics and Science Study for grades 4, 8, and 12. The comparative performance of boys with that of girls depends on the subject and grade level for most countries. In science, boys outperform girls in most countries in middle school (28 out of 39 countries) and in high school (in 20 out of 21 countries), but not in as many countries at elementary levels (10 out of 25). In mathematics, boys are much less likely to outperform girls in elementary school (3 out of 25 countries) or middle school (8 out of 39 countries), but at high school age, boys outperformed girls in 18 out of 21 countries. Interestingly, U.S. performance on the TIMSS assessments revealed no gender

Text table 5-4.

Trends in the percentage of students at or above benchmark levels of mathematics performance, by age and sex: 1977–96, selected years

Years	Male	Female
Age 9		
Level 200		
1978	69	72
1982	69	74
1986	74	74
1990	81	82
1992	82	81
1994	82	82
1996	83	81
Age 13		
Level 250		
1978	64	66
1982	71	71
1986	74	73
1990	75	74
1992	78	78
1994	79	77
1996	80	77
Age 17		
Level 300		
1978	55	48
1982	52	45
1986	55	49
1990	58	55
1992	61	58
1994	60	57
1996	63	58

SOURCE: National Center for Education Statistics (NCES). 1997. *NAEP 1996 Trends in Academic Progress*. NCES 97-985. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

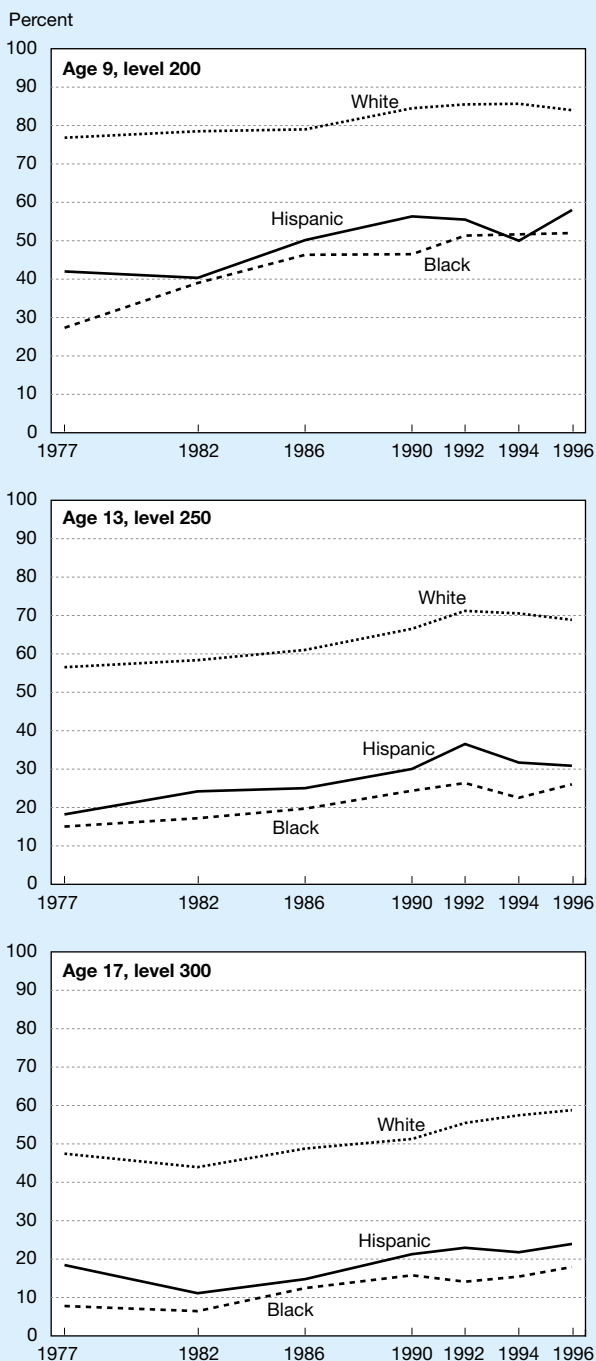
See appendix tables 5-9, 5-10, and 5-11.

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differences at any grade in mathematics. There were some differences detected between U.S. boys and girls in science at elementary and high school grades (not at middle school), but the differences were very small compared with other countries (Beaton et al. 1996a,b; Martin et al. 1997, 1998; and Mullis et al. 1997.)

Ethnic Differences in Performance. Comparisons of performance by racial/ethnic group are presented in figures 5-6 and 5-7. In science, more white, black, and Hispanic 9-year-olds reached benchmark (Level 200) in 1996 than in 1977. The change was particularly noteworthy for black students, who showed a 25 percentage-point increase from the initial assessment (27 percent) to the most recent one (52 percent). By comparison, the percentage of Hispanic students increased from 42 percent to 58 percent and the percentage of white students increased from 77 percent to 84 percent. As these numbers show, white students started off well ahead of black and Hispanic students in 1977 and remained well ahead through 1996. The disparity between white and black students at the 200 benchmark declined from 50 percentage points in 1977 to 32 percentage points in 1996. Changes in the white-Hispanic

Figure 5-6.
Trends in the percentage of students at or above
benchmark levels of NAEP science performance,
by age and race/ethnicity: 1977–96



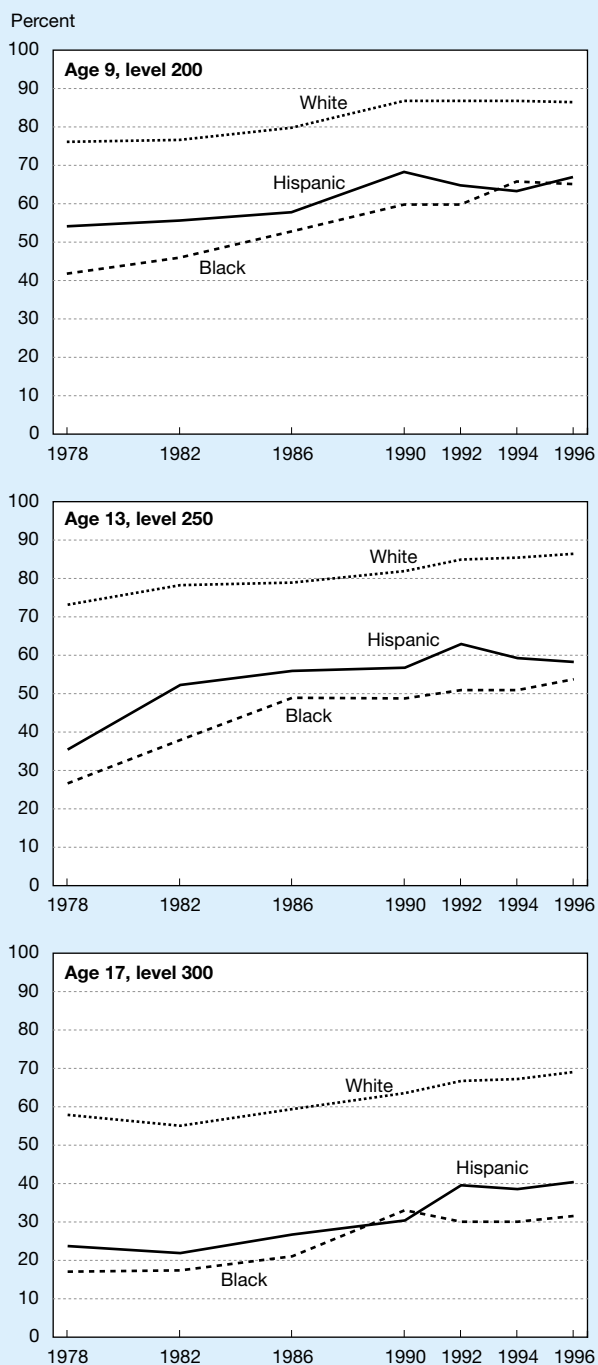
NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997.
NAEP 1996 Trends in Academic Progress. NCES 97-985.
Washington, DC: U.S. Department of Education, Office of Educational
Research and Improvement.

See appendix tables 5-6, 5-7, and 5-8.

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Figure 5-7.
Trends in the percentage of students at or above
benchmark levels of NAEP mathematics
performance, by age and race/ethnicity: 1978–96



NAEP = National Assessment of Educational Progress

SOURCE: National Center for Education Statistics (NCES). 1997.
NAEP 1996 Trends in Academic Progress. NCES 97-985.
Washington, DC: U.S. Department of Education, Office of Educational
Research and Improvement.

See appendix tables 5-9, 5-10, and 5-11.

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performance differences were more modest over that time period. The initial difference was 35 percentage points, while the difference in 1996 was 26 percentage points.

More 13-year-olds in all three racial/ethnic groups reached the benchmark (Level 250) on the science assessment in 1996 than in 1977. White students demonstrated a 12 percentage-point increase in reaching benchmark performance, black students a 10-point increase, and Hispanic students a 13 percentage-point increase. Again, white students started off well ahead of black and Hispanic students and this comparison continued through the years. Among 13-year-olds, performance differences between white-black and white-Hispanic groups did not narrow significantly over time.

Greater percentages of white and black 17-year-olds reached Level 300 in science in 1996 than in 1977, increasing by 11 and 10 percentage points, respectively. The proportion of 17-year-old Hispanic students achieving Level 300 increased by 5 percentage points. The upward trend in all three groups was statistically significant. As is the established pattern, more white students than black and Hispanic students attained Level 300 throughout the assessments.

In mathematics, significantly more 9-year-olds reached Level 200 in 1996 in all three racial/ethnic groups than in 1978. Black students showed the greatest improvement (from 42 to 65 percent) in reaching benchmark performance levels. White and Hispanic students showed increases of 11 and 13 percentage points, respectively. The disparity between white and black students but not that between white and Hispanic students decreased over this interval. The difference between white and black students reaching benchmark performance was 34 percentage points in 1978 and 22 percentage points in 1996.

There were improvements in the percentage of white, black, and Hispanic 13-year-old students reaching Level 250 between the first and most recent mathematics assessment. The differences between white and Hispanic students decreased from 37 percentage points in 1978 to 28 percentage points in 1996. The difference in performance between black and white students also decreased, from 44 to 32 percentage points. Major differences remained between the groups in 1996. About 86 percent of white students, 54 percent of black students, and 58 percent of Hispanic students scored at the benchmark level.

White, black, and Hispanic 17-year-olds functioned at significantly higher levels of mathematics performance in 1996 than in 1978. The increase for white students was from 58 percent to 69 percent; for black students, from 17 percent to 31 percent; and for Hispanic students, from 23 percent to 40 percent. As these numbers also reveal, white students held the edge from the first to the most recent assessment and no significant reduction in performance differences occurred from the first to the most recent assessment.²

²Appendix table 5-12 presents comparable trends information based on average scale scores.

Summary of NAEP Performance

Science and mathematics achievement in the early and middle grades have improved during the years in which trends assessments were conducted. Compared to 1977/78 performance levels, more 9- and 13-year-olds demonstrated understanding of simple scientific principles and could understand and apply general information from life and physical sciences in 1996. Mathematics achievement for these age groups also has improved since 1978. More 9- and 13-year-old students could perform two-digit addition and subtraction in 1996 than in 1978. More students also had command of the four basic arithmetic operations and could solve simple mathematical problems.

More 17-year-olds showed evidence of detailed scientific knowledge and evaluation of scientific procedures in 1996 than in 1977. More students also demonstrated mastery of one-step problems in 1996—a small but significant improvement. More 17-year-olds showed that they could compute with decimals and fractions and use moderately complex reasoning in 1996.

There also are negative aspects to these findings. Many 9-year-olds lack a good cognitive foundation on which to build future knowledge and understanding. About 70 percent of these students could not compute using whole numbers or could not solve one-step problems. More than 40 percent of 13-year-olds could not apply information from the life and physical sciences. About half of 17-year-olds could not evaluate scientific procedures and 40 percent were deficient in computation or in the use of moderately complex reasoning. Taken as a whole, the data suggest that, while definite improvements in achievement have occurred, the situation remains disappointing for black and Hispanic students. On average, black and Hispanic groups continued to score well below white students, even where there was some success in narrowing the gaps.

U.S. Achievement in an International Context

International assessments provide another perspective on U.S. achievement. The most recent study, the Third International Mathematics and Science Study (TIMSS), conducted in 1995, included assessment of fourth and eighth grade students as well as students in their final year of secondary school. The study included several components: the assessments, analyses of curricula for various countries, and an observational-video study of mathematics instruction in eighth grade classes in Germany, Japan, and the United States.

Achievement of Fourth and Eighth Grade American Students

TIMSS results for fourth and eighth grade students have been widely reported, including in the previous volume of S&E Indicators (NSB 1998). Often observers have expressed grave concern about the implications of TIMSS results for the science and mathematics education being provided to the

Nation's students. The National Science Board reports TIMSS' results in *Preparing Our Children: Math and Science Education in the National Interest* (NSB 1999). Among other issues critical to precollege education, the report recommended collaborative review of instructional materials by mathematics and scientists employed in knowledge-based industries, parents, and others. The report also recommended the partnership of teacher education instruction with relevant state and local agencies to create constructive alignment of teacher preparation, certification, and hiring practices and policies.

TIMSS findings are outlined here in only general terms. U.S. fourth grade students performed at competitive levels in both science and mathematics. In science, they scored well above the 26-country international average overall as well as in all content areas assessed—earth sciences, life sciences, physical sciences, and environmental issues/nature of science. Only students in South Korea scored at a higher level overall. (See figure 5-8, and appendix table 5-13.) The fourth grade assessment in mathematics covered topics in whole numbers; fractions and proportionality; measurement, estimation, and number sense; data representation, analysis, and probability; geometry; and patterns, functions, and relations. Fourth grade students also did well on this assessment, scoring above the international average and performing comparatively well in all content areas except measurement (NCES 1997c). (See figure 5-8 and appendix table 5-14.)

As with grade 4 students, the TIMSS science assessment taken by eighth grade students covered earth and life sciences and environmental issues, but also included content in physics and chemistry. With a mean score of 534 in science, grade 8 U.S. students scored above the 41-country international average of 516. (See figure 5-9.) U.S. students performed about at the international average in chemistry and physics, and above average on life sciences, earth sciences, and environmental issues (NCES 1997c). (See appendix table 5-15.)

Figure 5-9 shows that mathematics was the weaker area of eighth grade achievement. The assessment covered fractions and number sense; geometry; algebra; data representation and probability; measurement; and proportionality. Overall, eighth grade U.S. students performed below the 41-country international average and about at the international average in algebra, data representation, and fractions and number sense. Performance on geometry, measurement, and proportionality were below the international average. (See figure 5-9 and appendix table 5-16.)

Achievement of Students in the Final Year of Secondary School

The performance of students in the final year of secondary school can be considered a measure of what students have learned over the course of their years in school. Assessments were conducted in 21 countries to examine performance on the general knowledge of mathematics and science expected of all students, as well as more specialized content taught only in advanced courses.

Achievement on General Knowledge Assessments

The TIMSS general knowledge assessments were taken by all students, including those not taking advanced mathematics and science courses. The assessment covered earth sciences/life sciences and physical sciences topics covered in grade 9 in many other countries but not until grade 11 in U.S. schools. On the general science knowledge assessment, U.S. students scored 20 points below the 21-country international average, comparable to the performance of 7 other nations but below the performance of 11 other nations participating in the assessment. Only 2 of the 21 countries, Cyprus and South Africa, performed at a significantly lower level than the United States. (See figure 5-10.) It is noteworthy, however, that the countries performing similarly to the United States included Germany, Russia, France, the Czech Republic, Italy, and Hungary.

The general mathematics assessment covered topics most comparable to seventh grade material internationally and ninth grade material in the United States. Again, U.S. students scored below the international average, outperformed by 14 countries but scoring similarly to Italy, the Russian Federation, Lithuania, and the Czech Republic. As on the general science assessment, only Cyprus and South Africa performed more poorly. (See figure 5-10.) These results suggest that mathematics and science students in the United States appear to be losing ground to students in many other countries as they progress from elementary to middle to secondary school.

Achievement of Advanced Students

The TIMSS physics assessment was administered to students in countries who were taking advanced science courses and by U.S. students who were taking or had taken physics I and II, advanced physics, or advanced placement (AP) physics. The assessment covered mechanics and electricity/magnetism as well as particle, quantum, and other areas of modern physics.

Compared to their counterparts in other countries, U.S. students performed below the international average of 16 countries on the physics assessment. The mean achievement scores of the U.S. (423) and Austria (435) were at the bottom of the international comparison (average = 501). Students in 14 other countries scored significantly higher than the United States and no country achieved at a lower level. Advanced Placement physics students in the U.S. (not shown) scored 474 on the assessment, while 6 countries scored higher (scores ranging from 518 to 581). Only Austria performed at a significantly lower level, with a score of 435 (NCES 1998a).

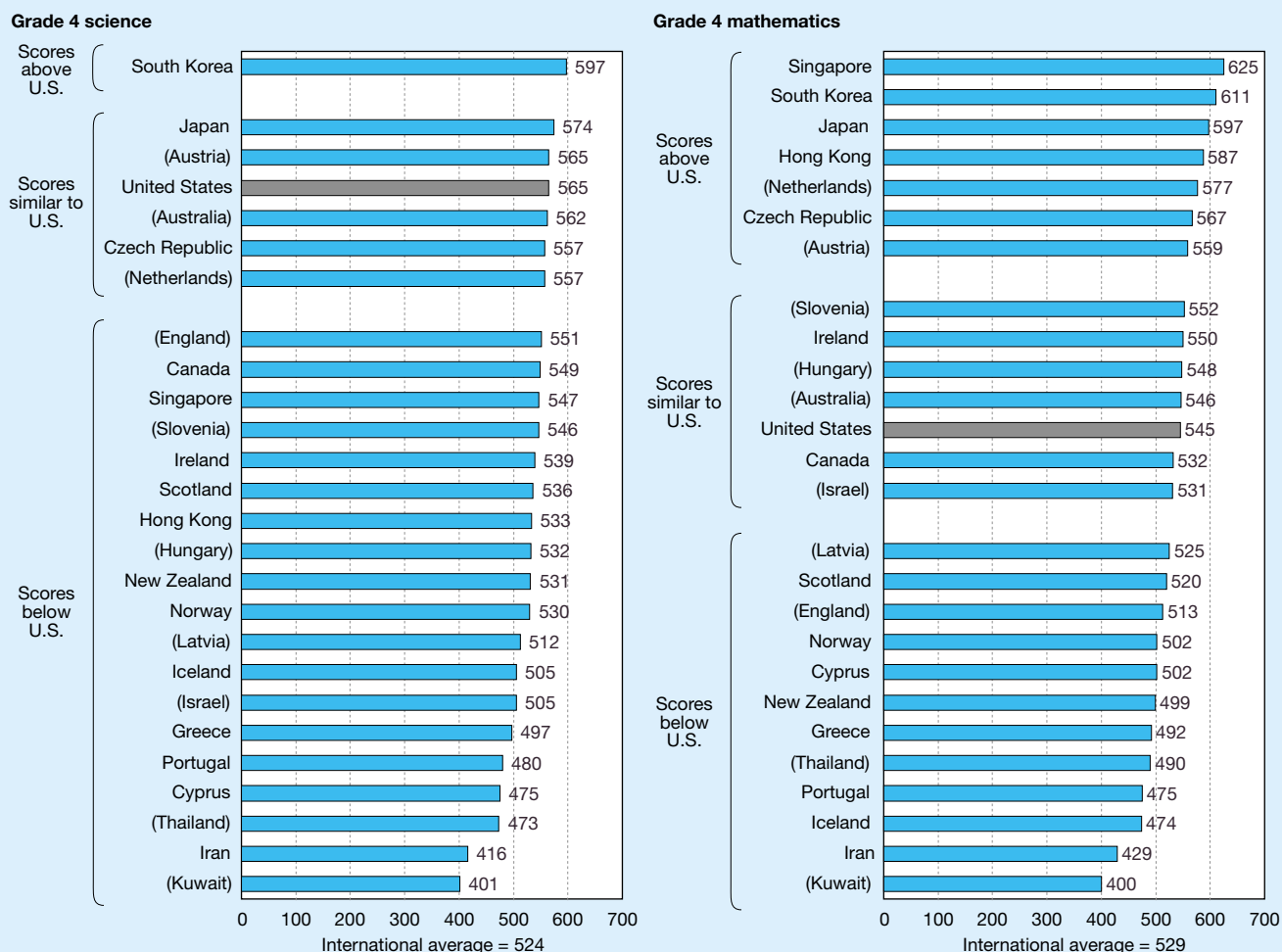
The advanced mathematics assessment was administered to students in other countries who were taking advanced mathematics courses and by U.S. students who were taking or had taken calculus, pre-calculus, or AP calculus. One-quarter of the items tested calculus knowledge. Other topics included numbers, equations and functions, validation and structure, probability and statistics, and geometry.

The international average on the advanced mathematics assessment was 501. American students, with a score of 442, were outperformed by students in 11 nations, whose average scores ranged from 475 to 557. No nation performed significantly below the United States, while Italy, the Czech Republic, Germany, and Austria performed at about the same level. (See figure 5-11.) U.S. students who had taken AP calculus (not shown) had an average score of 513, exceeded only by students in France. Five nations scored significantly lower than the AP calculus students in the United States.

Performance of the Highest Achievers

Contrasting the performance of the “best and brightest” American students with the best in other nations provides a comparison of the students in each country who are most likely to move through the educational pipeline to careers in science, mathematics, and engineering. One widely comparative index is the percentage of students in each country scoring within the top 10 percent of the students in all participating countries at all grade levels in international distribution. Data on this measure were reported only for grade 4 and grade 8 students.

Figure 5-8.
Average scale score on grade 4 TIMSS science and mathematics assessments relative to U.S. averages, by country: 1994–95



TIMSS = Third International Mathematics and Science Study

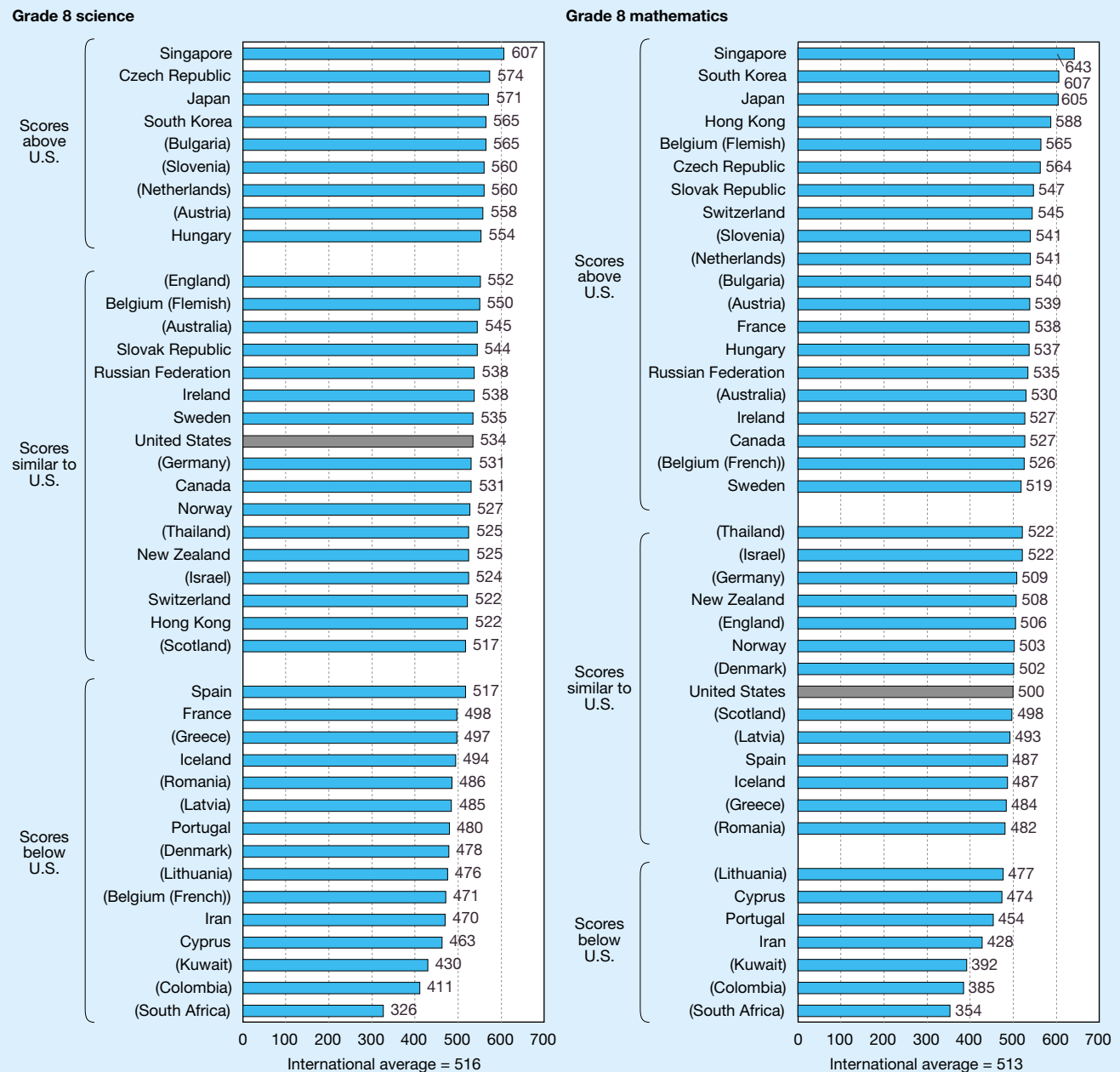
NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCES: Martin, M., I. Mullis, A. Beaton, E. Gonzalez, T. Smith, and D. Kelly. 1997. *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center; Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1997. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix tables 5-13 and 5-14.

Figure 5-9.

Average scale score on TIMSS science and mathematics assessments for students in grade 8, by country: 1994–95



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCES: Martin, M., I. Mullis, A. Beaton, E. Gonzalez, T. Smith, and D. Kelly. 1997. *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center; Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1997. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: Boston College, TIMSS International Study Center.

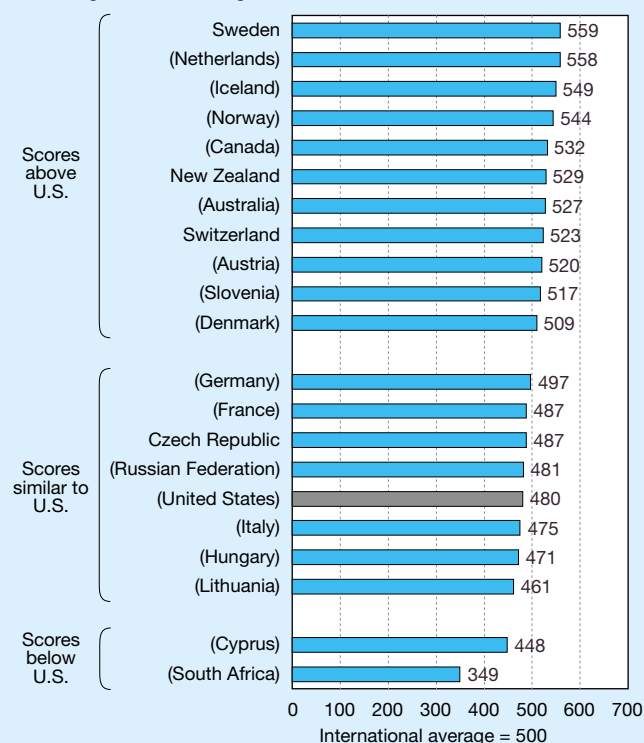
See appendix tables 5-15 and 5-16.

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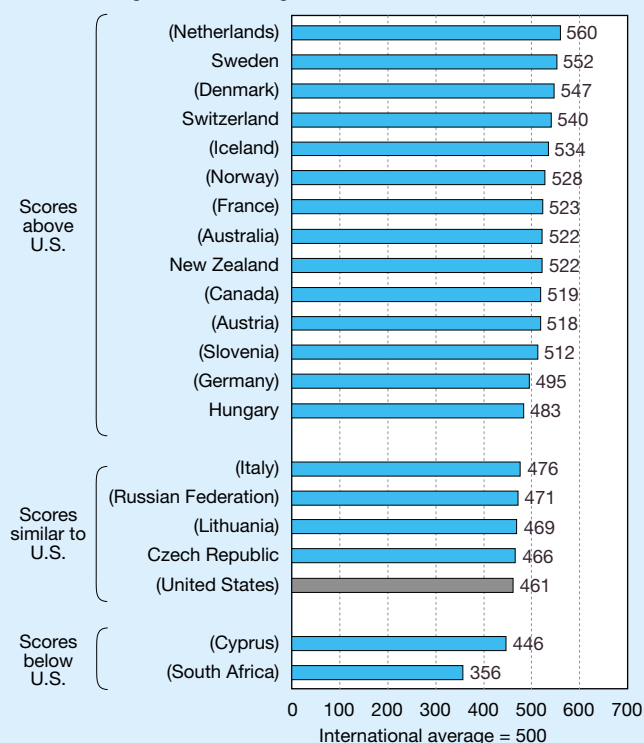
Figure 5-10.

Mean scale score on TIMSS general knowledge assessments in mathematics and science for students in their final year of secondary school: 1994–95

Science general knowledge



Mathematics general knowledge



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCE: Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1998. *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics Study*. Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix table 5-17.

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Relatively speaking, grade 4 students were the most internationally competitive of U.S. students. Sixteen percent of fourth grade U.S. students scored in the top 10 percent in science and 9 percent did so in mathematics. Thirteen percent of grade 8 students performed as well as the top 10 percent of TIMSS participants, but only 5 percent reached that benchmark in mathematics. (See appendix table 5-19.) Students in some U.S. schools are performing well above the national average and well above students from many other countries; schools in the First in the World Consortium are in this select group. (See sidebar, “First in the World Consortium Near the Top.”)

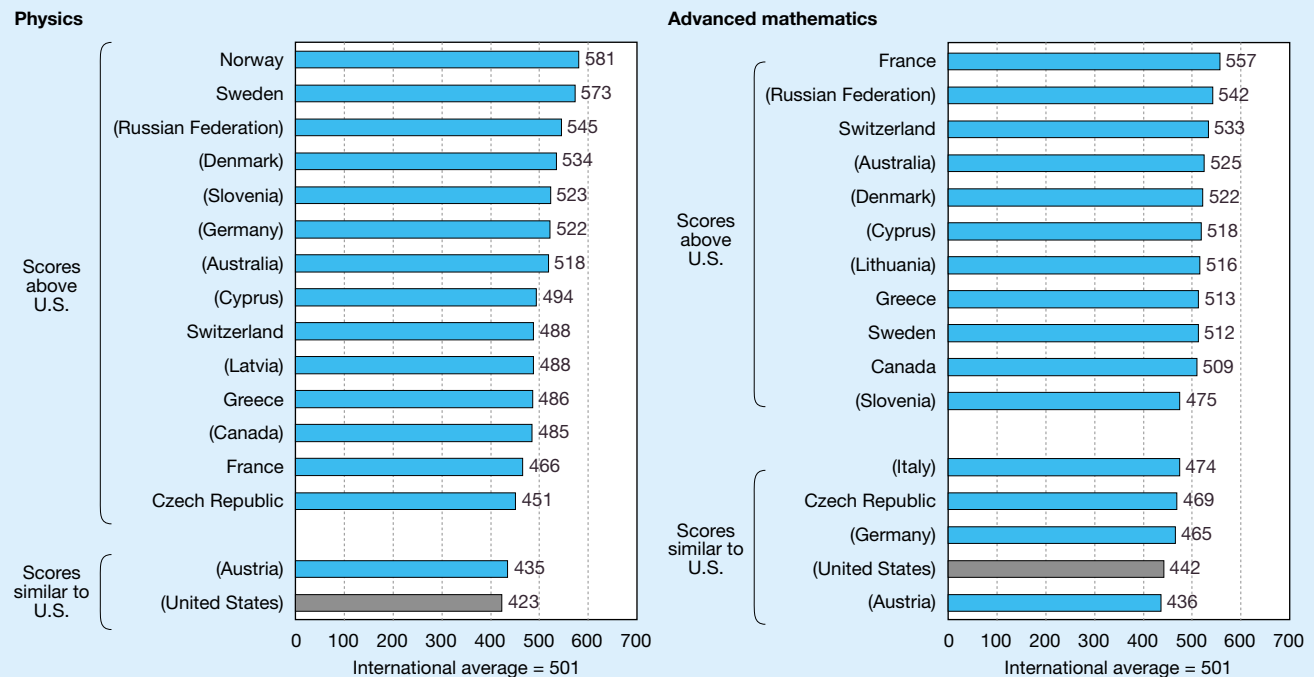
Performance of Students from the G-7 Nations

Of perhaps particular interest to policymakers is how well the U.S. students performed relative to the country's major trading partners, the six additional members of the “group of 7” (G-7): Canada, France, Germany, Italy, Japan, and the

United Kingdom (England, Scotland, Northern Ireland, and Wales). Because not all countries participated in each of the assessments, the potential comparisons are limited. A comparison of mean scale scores of the G-7 countries shows that on the science assessment the scores of fourth graders in the United States did not differ significantly from those in Japan and were higher than those of Canada, England, and Scotland. In 4th grade mathematics, Japanese students achieved a higher level than the United States, while the United States did not differ significantly from Canada and was higher than Scotland and England (NCES 1998b). (See figure 5-8.) On the grade 8 science assessment, only Japan outscored the United States, whose performance was comparable to that of England, Scotland, Canada, and Germany but better than France. In mathematics, the achievement of U.S. students was surpassed by that of students in Japan, France, and Canada, while U.S. students performed similarly to eighth grade students in Germany, England, and Scotland (Beaton et al. 1996a, b). (See figure 5-9.)

Figure 5-11.

Average scale score on TIMSS physics and advanced mathematics assessment for students in their final year of secondary school: 1994–95



TIMSS = Third International Mathematics and Science Study

NOTE: Nations not meeting international guidelines are shown in parentheses.

SOURCE: Mullis, I., M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. 1998. *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics Study*. Chestnut Hill, MA: Boston College, TIMSS International Study Center.

See appendix table 5-18.

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Summary of TIMSS Findings

In brief, the findings of the TIMSS assessments showed that U.S. students have higher achievement in science than in mathematics; that students in the primary grades demonstrated the strongest performance, especially in science; that students in grade 8 showed weaker performance; and that those in grade 12 showed weaker performance still, relative to their cohorts in other countries.

Science and Mathematics Coursework

In 1980, before *A Nation at Risk* motivated states to increase graduation requirements, 37 states had minimal graduation requirements on the books. By 1990, 43 states had specified the courses and number of credits needed for graduation. The National Education Commission on Time and Learning reports several studies showing that new requirements did not appreciably change the number of Carnegie units students were required to take. By one estimate, the average number of credits required for graduation in 1980 was 17. In 1990, the average was 20 credits, representing less than 10 percent difference over the 10 years (NECTL 1994).

The NECTL cites research indicating positive effects of strengthened graduation requirements. Schools offered more academic courses, particularly in mathematics and science, and more students, including minority and at-risk students, actually enrolled in the courses. The 1994 High School Transcript Study (HSTS), which examined the records of more than 25,000 graduating seniors, confirms that outcome. Students took more advanced science and mathematics courses in 1996 than did students who graduated in the late 1970s (NCES 1998e). In 1994, almost all graduating seniors (93 percent) had taken biology and more than one-half (56 percent) took chemistry. In comparison, 77 percent of 1982 seniors had completed biology and 31 percent had completed chemistry. In the class of 1994, almost one-quarter of graduates had completed physics, compared to 14 percent of 1982 graduates. (See figure 5-12 and text table 5-5.) Appendix table 5-21 provides participation rates for advanced placement and other science courses.

In 1994, more graduating students had taken advanced mathematics courses than did their counterparts in prior years. In 1994, 58 percent of students took algebra 2, compared to 36 percent in 1982. The 1994 participation rates for geometry and calculus were 70 percent and 9 percent, respectively.

First in the World Consortium Near the Top

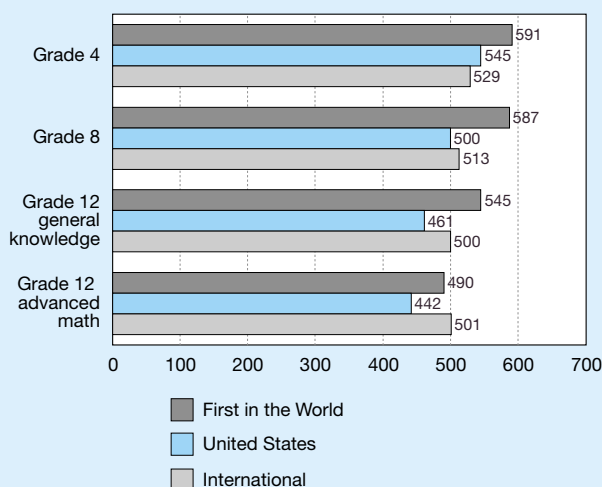
The First in the World Consortium was started by a group of North Shore school superintendents in Illinois to work collectively on specific administrative issues. One of their last meetings focused on Goals 2000 (legislation that called for national goals and world-class standards). From this discussion came a commitment to create a regional consortium of districts driven by the need to pursue a world-class education for their students.

Schools in the First in the World Consortium showed quite strong performance on all TIMSS assessments. They scored well above the general population of U.S. students and above the international mean at all three grades and on both the general knowledge and advanced exams in mathematics and science at the end of secondary school.

Highest scoring country				
Grade	Mathematics		Science	
4	Singapore	625	South Korea	597
8	Singapore	643	Singapore	607
12 Literacy	Netherlands	560	Sweden	559
12 Advanced ...	France	557	Norway	581

SOURCE: IEA Third International Mathematics and Science Study, 1994-95.

Mathematics



Science

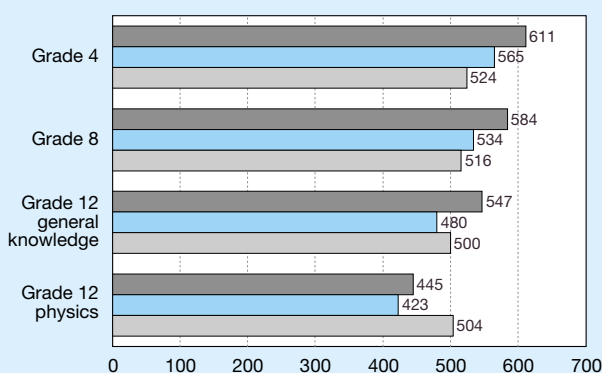
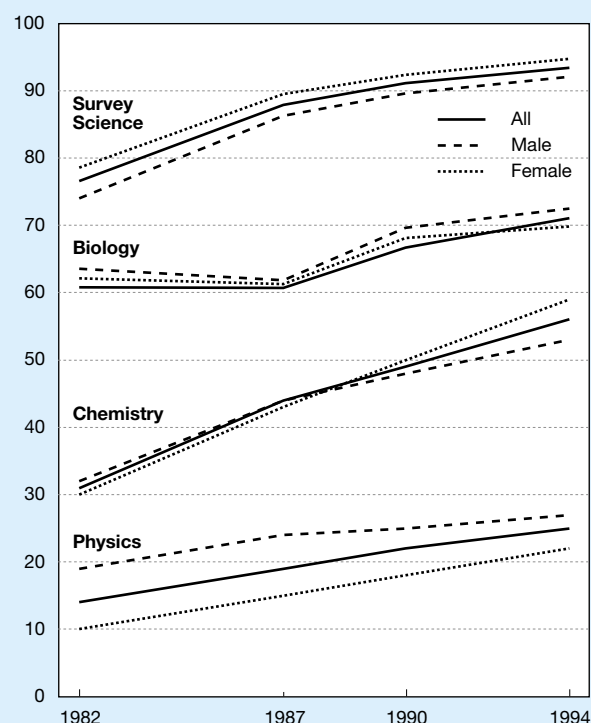


Figure 5-12.
Percentage of high school graduates taking
science courses, by gender: 1982-94



SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-21 & 22.

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Corresponding figures for 1982 were 46 percent in geometry and 5 percent in calculus. From 1982 to 1994, there was a corresponding decrease in lower-level courses such as general mathematics, which dropped from 30 percent to 16 percent for 1994 over that period. (See figure 5-13 and text table 5-6.) Refer to appendix table 5-22 for information on other mathematics courses, including AP calculus (NCES 1998e).

Gender Differences in Course Participation. The association between courses taken in high school and later educational outcomes has been established for some time (Sells 1978 and Smith 1996). Given the lower representation of women throughout the science, mathematics, and engineering pipeline, there has long been an interest in tracking gender differences in the patterns of advanced science and mathematics courses taken. Data from the recent transcript study show that, in 1982, approximately 79 percent of female graduates completed biology, 30 percent completed chemistry, and 10 percent completed physics (NCES 1998e). The corresponding numbers in 1994 were 95 percent, 59 percent, and 22 percent, respectively. For males, 74 percent completed biology in 1982 and 92 percent in 1994, 32 percent

Text table 5-5.

Percentage of high school graduates earning credits in science courses, by gender and race/ethnicity: 1982 and 1994

Year of graduation and characteristic	Survey science	Biology	Chemistry	Physics
1982				
All	62	77	31	14
Male	64	74	32	19
Female	61	79	30	10
White	62	79	34	17
Asian/Pacific Islander	41	84	53	35
Black	68	73	22	8
Hispanic	63	69	16	6
American Indian/Alaskan Native	58	67	26	8
1994				
All	71	93	56	25
Male	73	92	53	27
Female	70	95	59	22
White	72	94	58	26
Asian/Pacific Islander	62	92	69	44
Black	72	92	44	15
Hispanic	70	94	46	16
American Indian/Alaskan Native	79	92	41	10

SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-21 and 5-23.

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completed chemistry in 1982 and 53 percent in 1994, and 19 percent completed physics in 1982 and 27 percent in 1994. For both male and female graduates, the biggest percentage-point increases were in physics. In all three of these advanced science courses, differences between male and female participation decreased from 1982 to 1994. (See figure 5-12, text table 5-5, and appendix table 5-21.)

Both male and female students took more advanced mathematics courses in 1994 than in 1982. For both genders, completion rates for algebra 2 and geometry increased 19 to 26 percentage points. The percentages of male and female students completing calculus doubled over that period, reaching almost 10 percent for both genders in 1994. In 1994, approximately 54 percent of male students and 61 percent of female students completed algebra 2 and 68 percent of males and 72 percent of females completed geometry. (See figure 5-13, text table 5-6, and appendix table 5-22.)

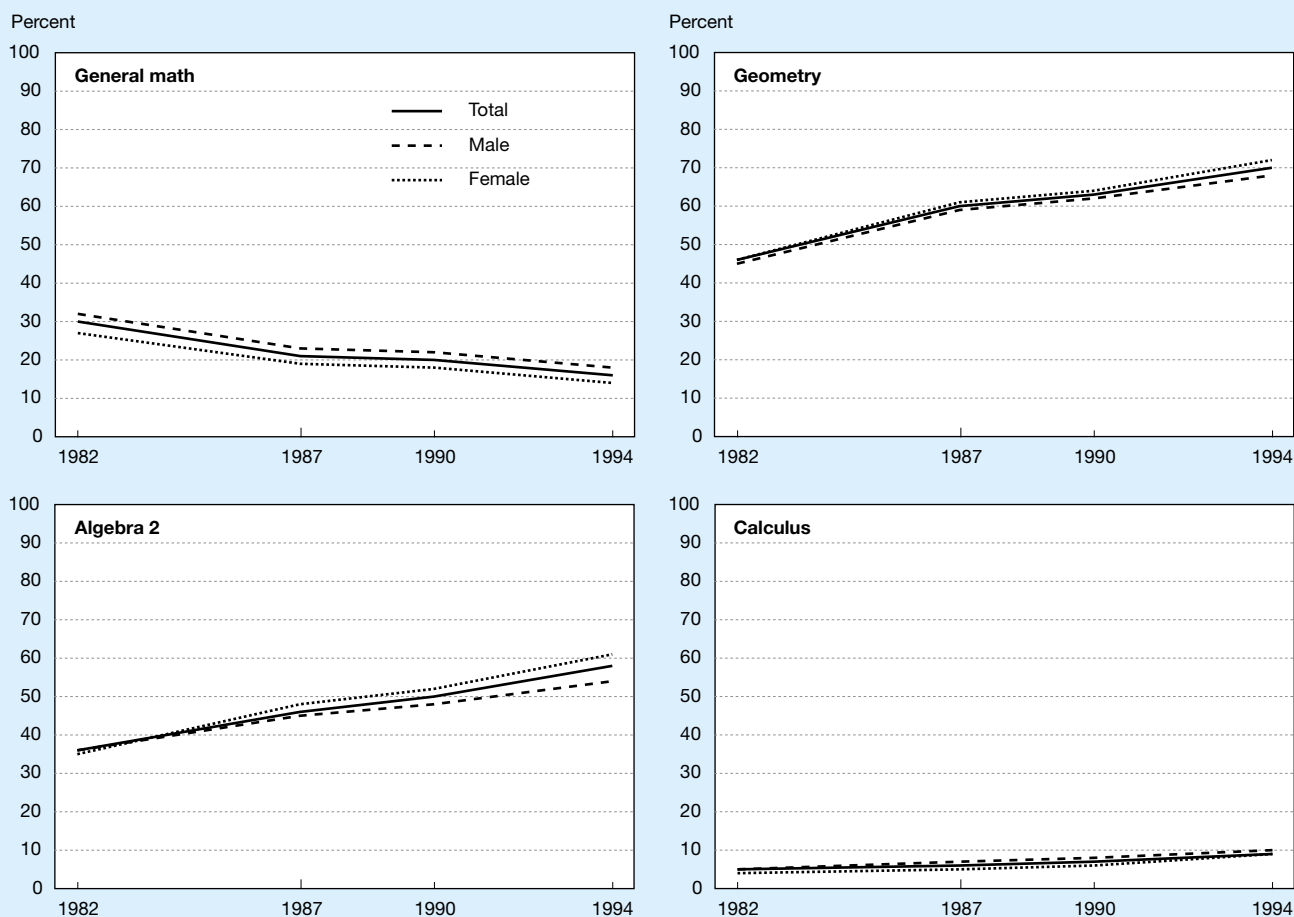
Ethnic Differences in Course Participation. Educators have also tracked course taking patterns by ethnic group (NCES 1998e). Students from racial and ethnic groups that are typically underrepresented in science made substantial gains in their proportions taking advanced science courses. More than 90 percent of black, Hispanic, and American Indian/Alaskan Native students now complete biology. In chemistry, the proportion of black students completing chemistry doubled between 1982 and 1994 (from 22 to 44 percent), the completion rate for Hispanic students nearly tripled (from 16

to 46 percent), and for American Indian/Alaskan Natives, the proportion increased by more than one-half (from 26 to 41 percent). All categories made progress in physics course taking between 1982 and 1994, although the proportions of students from black, Hispanic, and American Indian/Alaskan Native groups remained 16 percent or lower in 1994. Corresponding 1994 rates for white and Asian/Pacific Islander students were 26 percent and 44 percent, respectively. (See figure 5-14 and text table 5-5.)

Figure 5-15, which shows the pattern of higher-level mathematics courses completed by ethnic group, indicates that more high school seniors in all ethnic groups completed advanced mathematics courses in 1994 than in 1982. Increases for white and Asian/Pacific Islander students are evident in geometry, algebra 2, and calculus. Increases were also apparent for students in racial/ethnic groups that typically are underrepresented in mathematics and the sciences.

For American Indian/Alaskan Natives, the course completion rate for algebra 2 increased from 19 percent to 42 percent; for geometry the rate moved from 34 to 60 percent. The proportion of black students completing algebra 2 increased from 24 percent to 44 percent; for geometry, the increase was from 29 to 58 percent. The geometry completion rate of Hispanics increased from 26 to 69 percent and in algebra 2 from 20 to 50 percent. In 1994, about one-quarter of Asian/Pacific Islander students completed calculus compared with about 10 percent of whites, 6 percent of Hispanics, and 4 percent each of black

Figure 5-13.

Percentage of high school graduates earning credits in selected mathematics courses, by gender: 1982–94

SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix table 5-22.

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and American Indian/Alaskan Native students. In 1994, the familiar pattern of course completions held. In 1994, as in 1982, more white and Asian/Pacific Islander students completed advanced mathematics courses. (See figure 5-15.)

Research is mixed as to whether the positive effects of stronger requirements were counterbalanced by negative effects. For example, minority and at-risk students failed more courses than before mandates were put into practice (NECTL 1994). Opinions differ on the quality of the added courses, especially those taken by low achieving students. There was particular concern about the quality of new courses designed for low achievers, who, under the traditional pipeline, would have taken general or basic mathematics. Some research suggests that most of the new courses mandated by increased graduation requirements were remedial, low level, or basic rather than advanced (Porter, Smithson, and Osthoff 1994).

Other recent studies have come to a different conclusion. Studying 18 high schools in 12 districts in 6 states, Porter,

Smithson, and Osthoff (1994) found no evidence that the newer courses were diluted. Gamoran's (1996) research replicated this finding and also reported that bridging courses achieved some success. Bridging courses helped ease the transition of lower achieving students to college-preparatory courses. The question has great relevance to education policy as schools in Boston require all ninth grade students to take algebra, and schools in New York City require all students to take academic mathematics and science courses during their first two years of high school. Gamoran's research also showed that students who took bridging courses were not as academically successful as students taking college-preparatory mathematics; however, their success was greater than that of students who had taken general mathematics courses (Gamoran 1996).

On balance it appears too early to draw general conclusions about the quality of these new courses. The studies cited here—both confirming and disconfirming that the

Text table 5-6.

Percentage of high school graduates earning credits in mathematics courses, by gender and race/ethnicity: 1982 and 1994

Year of graduation and characteristic	Mathematics course			
	General Math	Algebra 2	Geometry	Calculus
1982				
All	30	36	46	5
Male	32	36	45	5
Female	27	35	46	4
White	25	40	51	5
Asian/Pacific Islander	17	56	65	13
Black	47	24	29	1
Hispanic	43	20	26	2
American Indian/Alaskan Native	41	19	34	4
1994				
All	16	58	70	9
Male	18	54	68	10
Female	14	61	72	9
White	15	62	72	10
Asian/Pacific Islander	18	66	76	24
Black	27	44	58	4
Hispanic	16	50	69	6
American Indian/Alaskan Native	19	42	60	4

SOURCE: National Center for Education Statistics (NCES). 1998. *The 1994 High School Transcript Study: Comparative Data on Credits Earned and Demographics for 1994, 1990, 1987, and 1982 High School Graduates*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

See appendix tables 5-22 and 5-24.

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courses were diluted—were conducted in only a handful of states and school districts, and in a handful of courses. Moreover, the earlier studies appear to have been conducted not long after the mandates were enforced. Thus, there may have been little opportunity for revisions and improvement.

Curriculum and Instruction

Challenging instruction is at the core of new educational standards. Both the science and mathematics standards present compelling visions of instruction, although neither provides an exact blueprint. Measuring the extent to which this vision is becoming a reality is difficult because available methodologies cannot measure quality directly. Instead, educational researchers have relied most often on indicators of the amount of time students spend studying a subject (classwork and homework) and the content of lessons, as well as the use of instructional resources such as textbooks and technology. Lacking, until quite recently, were indicators that better reflect instruction as a process.

Instructional Time

The question of whether U.S. students spend enough time in school or receiving instruction has persisted for many years and research results on this issue are mixed. Research by

Stigler and Stevenson (1991) showed that U.S. students spend fewer hours in school than Japanese students and that U.S. schools allocate less time to core instruction than do other industrialized nations. For example, core academic time in U.S. schools was estimated at 1,460 hours during the four years of high school compared to 3,170 hours in Japan. The National Educational Commission on Time and Learning reported in 1994 that, at the time of the Commission's study, only 10 states specified the number of hours to be spent in academic subjects at various grades. Only 8 others provided recommendations regarding academic time. Based on these and other findings, the Commission concluded that "[T]ime is the missing element in the debate about the need for higher academic standards.... We have been asking the impossible of our students—that they learn as much as their foreign peers while spending only half as much time in core academic studies" (NECTL 1994).

TIMSS data suggested that this may not have been true of mathematics and science in 1995. Students in the United States receive at least as much classroom time in mathematics and science instruction as students in other nations—close to 140 hours per year in mathematics and 140 hours per year in science. Students in Germany, Japan, and the United States spent about the same time on a typical homework assignment, but U.S. students were assigned homework more often, thus increasing total time spent studying in the two subjects (Beaton